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Case Report

# The forensic importance of frontal sinus radiographs

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**Abstract**

The identification of unidentified human remains through the comparison of antemortem and postmortem radiographs has found wide acceptance in recent years. Reported here is the forensic case of an unidentified adult male who had died as the result of a traffic accident, after which the body was identified by matching images of ante- and postmortem radiographs of the frontal sinus. A general discussion on identification using frontal sinus radiographs is presented, highlighting the reliability of this method, in reference to the uniqueness of the frontal sinus in humans. However, it also notes a few difficulties, especially in reference to the X-ray technique in cases where antemortem radiographs are available and a potentially larger number of anatomical, pathological or traumatic features are present. The comparison of frontal sinus outlines is recommended when it may become necessary to provide quantitative substantiation for forensic identification based on these structures.


*Keywords:* Frontal sinus; Radiography; Forensic anthropology; Victim identification

## Introduction

The use of imaging exams in legal matters has been described in forensic literature both in cases of lawsuits against healthcare professionals[1] and in cases of human identification. In the latter, computerized tomography (CT) scans[2] and X-rays performed with medical [3] or dental referral [4–6] can be useful tools in forensic investigations, as these examinations display different singularities of the anatomical structures analyzed.

Specifically in the skull, several types of radiographs can be taken by using particular models of panoramic or medical X-ray machines. Medical or dental referrals for skull radiography allow for the analysis of numerous anatomical structures, such as the cranium, paranasal sinuses, zygomatic process and nasal cavity. Moreover, radiographic analysis makes it possible to identify any foreign objects or intracranial calcification, evaluate symmetry or identify craniofacial bone fractures, in addition to assisting in the

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planning of specific treatments, such as orthodontic tracing and orthognathic or implant surgery.

The anatomical complexity of the facial skeleton has prompted the development of several types of radiographic techniques. Among those more commonly used is the posteroanterior (PA) view of the skull, also known as the Caldwell view. Its application is normally associated with the radiographic evaluation of frontal and ethmoidal sinus morphology, making it also possible to identify calvarial bone fractures.

Knowing that in addition to having clinical purposes, PA skull radiographs can also be used for legal purposes, the aim of the present study was to demonstrate, by means of a case report, the importance of frontal sinus radiographs for human identification in forensic investigations.

## Case report

In June 2005, an unidentified adult male was killed as the result of a traffic accident. The body was taken to the local coroner's office for a routine autopsy, in order to determine the cause and circumstances of his death, as well as the instrument that ultimately caused his demise. After 30 days, the victim remained unidentified, without matching any missing-person report. Therefore, prior to routine burial procedures, postmortem facial photographs, fingerprints and DNA material were collected.

The victim's family members carried out an intensive search for the body in several local and regional hospitals, as well as in different morgues in the area, given that the victim had been missing for a considerable period of time. The victim was eventually identified from postmortem photographs at the "unclaimed corpses" section of the Goias Coroner's Office. Immediately, a request was made for the records containing the victim's fingerprints, which should have been filed at the local Civil Identification Records Department. However, the records in question, containing the fingerprints taken while this individual was alive, could not be located, making it necessary to use another method for identification. Therefore, a subsequent request was made to the presumed family members for any type of medical, dental or photographic documentation related to the yet-unidentified person.

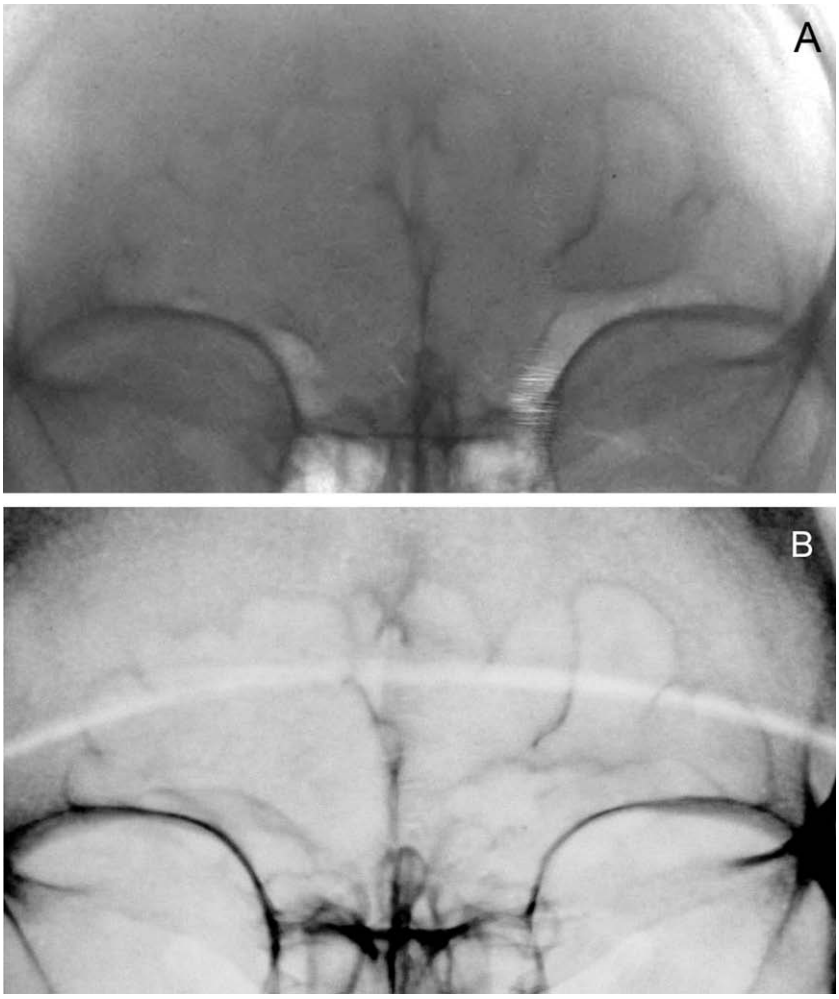


Fig. 1. Diagram of Caldwell radiographic technique for antemortem (A) and postmortem (B) examination of the frontal sinus.

The results of this investigation showed the existence of dental records containing periapical radiographs, seven radiographs of the torso (thorax and abdomen), one CT scan and two skull X-rays – a lateral and a PA radiograph (Fig. 1A). These medical examinations had all been carried out in 1999, as the result of treatment for another traffic accident, in which the victim suffered neurological damage as a result of brain trauma.

In view of this new possibility for identification, the body was exhumed approximately one year after burial. The body showed considerable soft-tissue decomposition, such that only the skull and jawbone were obtained for

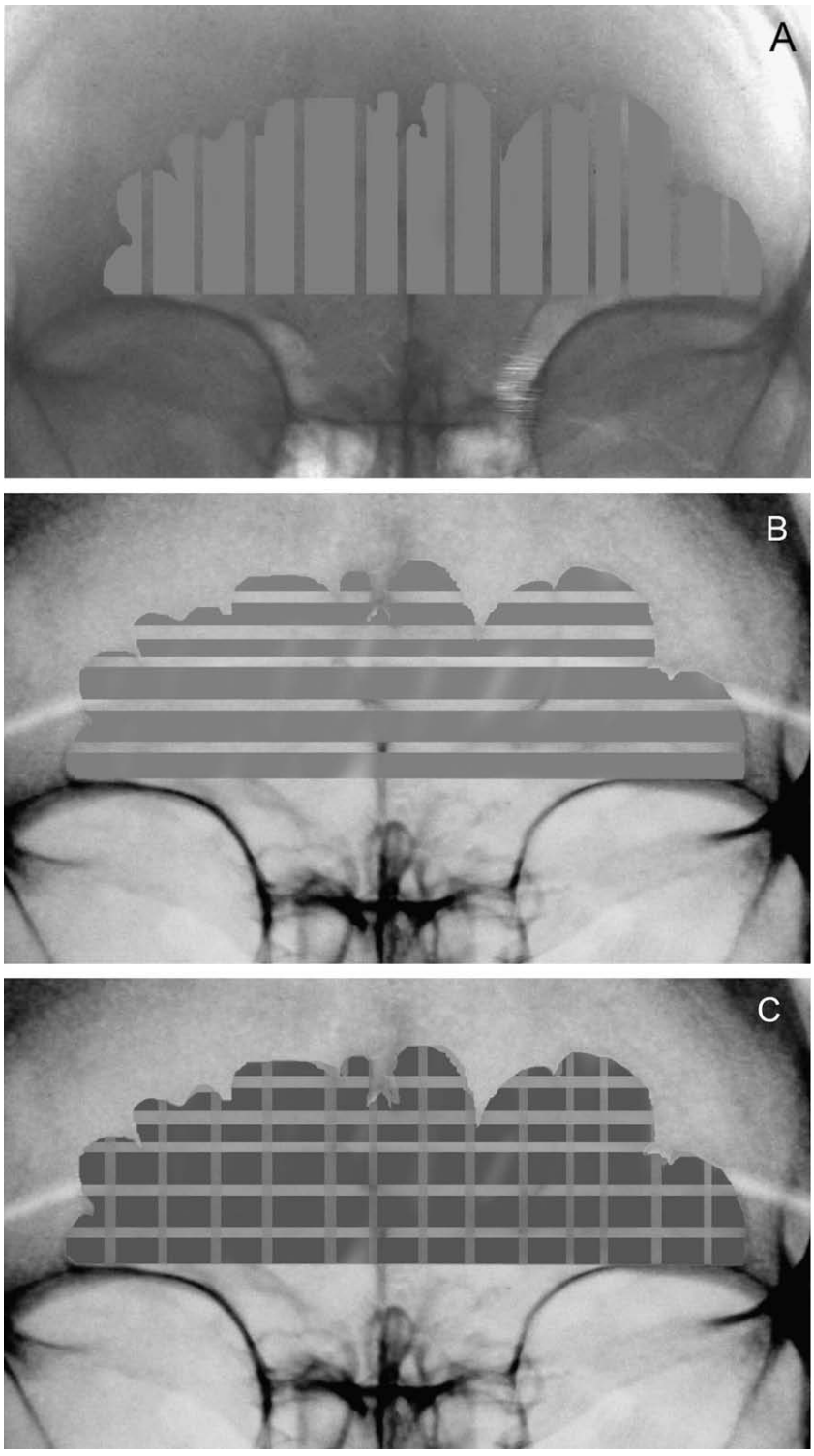


Fig. 2. Steps of computerized superimposition: antemortem image with vertical columns (A), postmortem with horizontal lines (B) and convergent superimposition area (C).

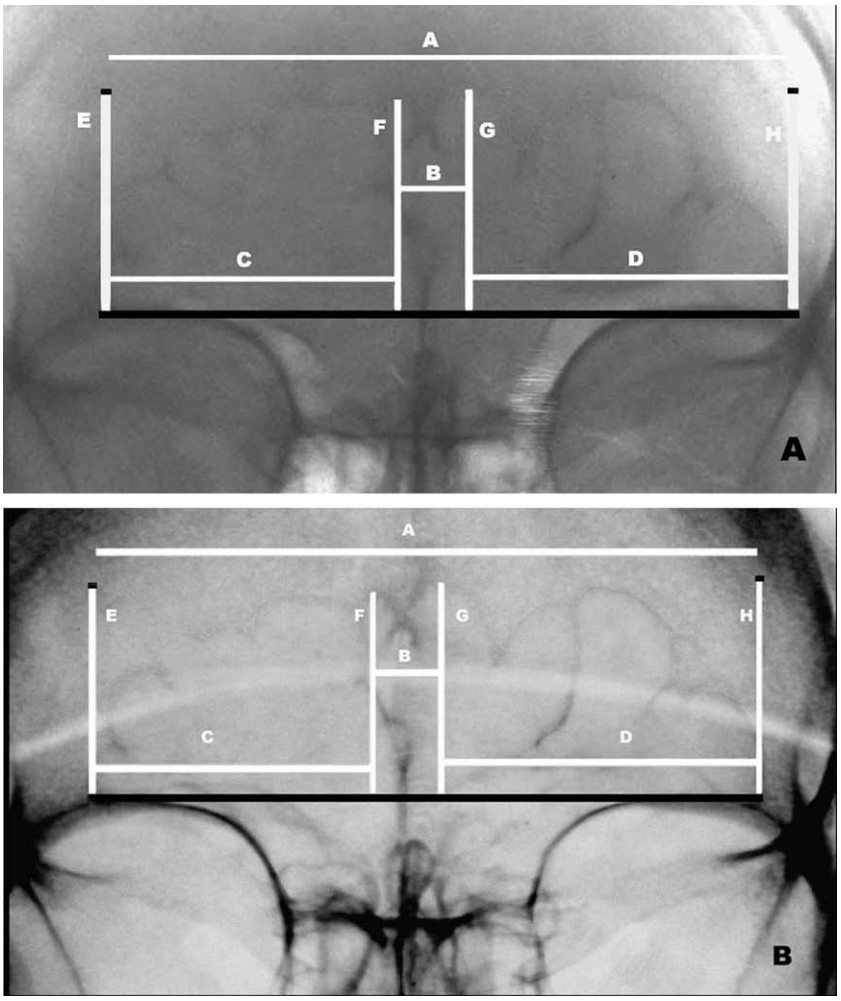


Fig. 3. Points of reference and measurements according to Oliveira,[8] performed in antemortem (A) and postmortem (B) radiographs of the frontal sinus.

examination. These parts were adequately cleaned, allowing for postmortem radiographic examination (Fig. 1B), using suitable techniques and apparatus according to Raitz et al.[7]

The radiographic images obtained in life and at postmortem were digitized, their luminescence was inverted, and the brightness/contrast were adjusted in order to better visualize the contours and outlines of the frontal sinus. Three different methods were used to analyze the antemortem and postmortem radiographic images: direct comparison, computed superimposition using Adobe Photoshop® software (Fig. 2), and measurements; the latter were performed according to the anatomical points described by Ribeiro.[8] That author recommends the measurement of five reference lines on X-ray images, where the first is drawn through the upper edge of the eye sockets and the others are drawn perpendicular to the first line, from the following points: the outermost point of the right frontal sinus; the outermost point of the left frontal sinus; the uppermost point of the right frontal sinus; and the uppermost point of the left frontal sinus. After establishing these parameters, measurements were taken of the maximum width of the frontal sinus, the distance between the right and left uppermost points of the frontal sinus, and the distance between the uppermost and the outermost point of each side of the frontal sinus (Fig. 3). The results were obtained through measurements performed directly on the X-rays, and it was detected that the values did not match when comparing the same reference point in the antemortem and postmortem images (Table 1). This difference in absolute values can be explained by changes in the positioning of the skull while the radiograph was taken, by radiographic distortion, and by the absence of soft tissues (postmortem), among other factors.[9] However, it should be observed that the ratios between the values obtained in life and postmortem are the same – a finding that indicates the validity of the applied technique.

## Discussion

Anatomically, the frontal sinuses can be defined as pneumatic cavities covered by mucosa, located between the internal and external cortical bones of the frontal bone.[10] Although these cavities are not visible at birth and at the start of their development during the second year of life, they are radiologically evident structures at five

Table 1
Points of reference and measurements in centimeters, according with parameters proposed by Ribeiro[8]

| Parameter | Antemortem | Postmortem | Ration of antemortem/ postmortem |
|---|---|---|---|
| A – diameter of frontal sinuses at the most lateral points = B + C + D | 10.2 | 8.9 | 0.87 |
| B – distance between the projected lines marking the highest points of the right and left sinuses | 2.0 | 1.6 | 0.80 |
| C – distance between the projected lines marking the maximum lateral limit and the highest point of right frontal sinus | 3.5 | 3.1 | 0.88 |
| D – Distance between the projected lines marking the maximum lateral limit and the highest point of left frontal sinus | 4.7 | 4.2 | 0.89 |
| E – line delineates the maximum lateral limit of the right frontal sinus | – | – | – |
| F – distance between upper limit of orbital cavities and highest point of the right frontal sinus | 3.4 | 2.8 | 0.82 |
| G – distance between upper limit of orbital cavities and highest point of the left frontal sinus | 3.3 | 2.9 | 0.87 |
| H – line delineates the maximum lateral limit of the left frontal sinus | – | – | – |

or six years of age, developing during the later stages of puberty and becoming completely developed by approximately 20 years of age.[11,12] In relation to its shape, the frontal sinus is normally bilateral, asymmetric, having one septum that separates the right and left sides.[12] This morphology remains practically unchanged during one's entire adult life, although some environmental factors can modify its structure, such as hyperpneumatization from sports activities, illnesses, infections, tumors or trauma, among others. [8,11]

Frontal sinus uniqueness was initially observed by Zuckerkandl (1895),[13] who called attention to its asymmetric morphology. This uniqueness piqued the interest of other researchers, and Schuller (1943) [14] showed evidence that there was no morphologic equivalence of this structure – not even in monozygotic twins – thereby suggesting the possibility of identifying people by comparing X-rays. Culbert and Law (1927)[15] described the first human identification through morphologic analysis of the frontal sinus to be accepted in a court case in the United States.

Since this historical landmark and up to the present day, other cases of human identification through the analysis of frontal sinus morphology, using PA radiographs[3,11,12,16–22] as well as CT scanning,[2,23–25] have been described. The method used for the positive determination of identity normally involves the comparison of the characteristics obtained from radiographic images taken in life and those taken postmortem. This comparative analysis is based on the experience of the observer, who determines the convergence points when comparing the two situations. Due to the need for establishing an objective method, with the possibility of reproducibility in similar situations, some authors have considered technical parameters for the analysis of frontal sinus morphology, using specific points to derive pre-established measurements.[8,21,26,27] The search for objective parameters is justified by the desire to obtain indisputable forensic evidence when analyzing documents of criminal cases.[28]

Due to the fact that the frontal sinus is absent in only 4% of the population, and with substantial variations in its morphology, area and symmetry,[12] it constitutes a parameter of great importance for human identification. In certain cases, the analysis of frontal sinus measurements even makes it possible to determine sexual dimorphism. Therefore, posteroanterior radiographs of the skull, with the application of the correct techniques and appropriate processing standards, are indispensable.[22]

## Final considerations

Although DNA analysis is precise and provides reliable results, this type of testing is not yet used routinely in forensic investigations performed by almost any forensic medicine departments in Brazil, including the unit where the present research was conducted. Therefore, the methods of human identification using anthropological and dental forensic parameters continue to be used, due to their relative low cost and processing time, allowing for precise and reliable results.

Within this context, it was possible to establish the identity of the examined corpse as belonging to the missing person, because antemortem radiography was adequate – a factor that allowed the combined use of different techniques for radiographic analysis of the frontal sinus. Therefore, in addition to its significant usefulness in identifying traumatic and pathological conditions of the frontal sinus, posteroanterior radiographs of the skull also allow the study of the morphology of these structures, which is very useful in human identification.

## Conflict of interest

None declared.

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